IBS suppression lattices

Vladimir N. Litvinenko

on behalf of IBS-suppression lattice development team

Mei Bai, Don Bruno, Roger Connolly, John Cupolo,
Alexei Fedotov, George Ganetis, Yun Luo,
Aljosa Marusic, Christoph Montag, Vadim Ptitsyn,
Todd Satogata, Steve Tepikian, Nick Tsoupas
and more

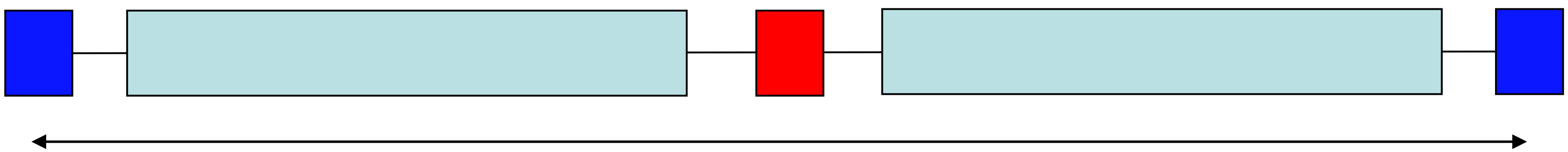
Content

- **Reminder: what is IBS suppression lattice?**
- Where we are?
- What are next steps?
- Conclusions

Transverse IBS in RHIC

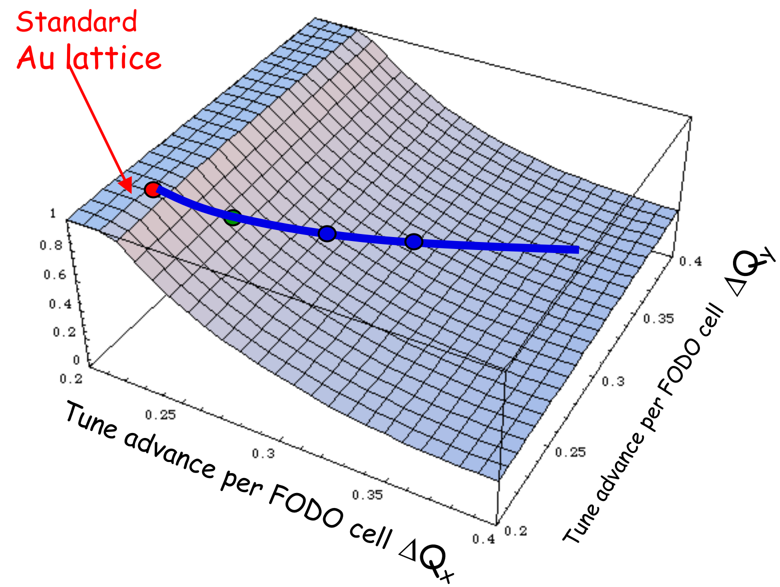
The main contribution to the transverse IBS in RHIC come from the arcs, most of which comprised of FODO cells

$$\frac{d\varepsilon_x}{ds} = H(s)\cdot\frac{d\delta_E^{\,2}}{ds};\qquad H(s) = \gamma_x D_x^2 + 2\alpha_x D_x D_x' + \beta_x D_x'^2$$

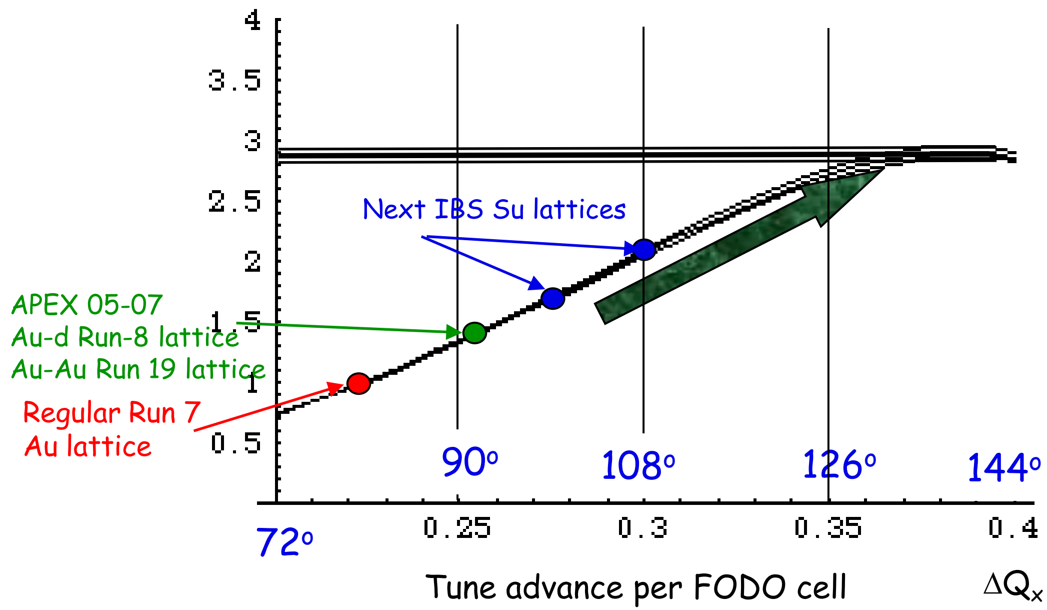


$$\frac{d\delta_E^{\,2}}{ds} \propto \frac{N}{\sigma_s \sigma_r^2 \sigma_{r'}};\qquad H_{\mathrm{mod}}(s) = \frac{H(s)}{\sqrt{\beta_y(1+\alpha_x^2)+\beta_x(1+\alpha_y^2)}}$$

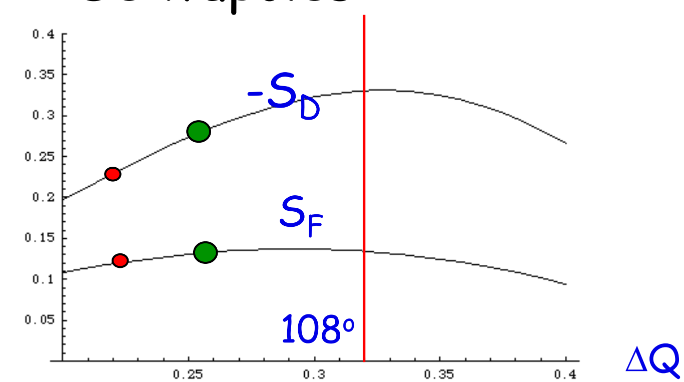
Idea: 2004



Suppression of transverse IBS



Sextupoles



BROOKHAVEN NATIONAL LABORATORY

IBS suppression lattice:

3 years, 17 people

Mei Bai, Don Bruno, Peter Cameron, Roger Connolly,
John Cupolo, Al Della Penna, Alexei Fedotov, George Ganetis,
Vladimir Litvinenko, Yun Luo, Nikolay Malitsky,
Aljosa Marusic, Christoph Montag, **Vadim Ptitsyn**,
Todd Satogata, **Steve Tepikian**, Nick Tsoupas

BROOKHAVEN
NATIONAL LABORATORY

Run-7 - IBS suppressed

Long story full of surprises (perfect tune feed-back ramp in blue followed by problem with SC splice….)

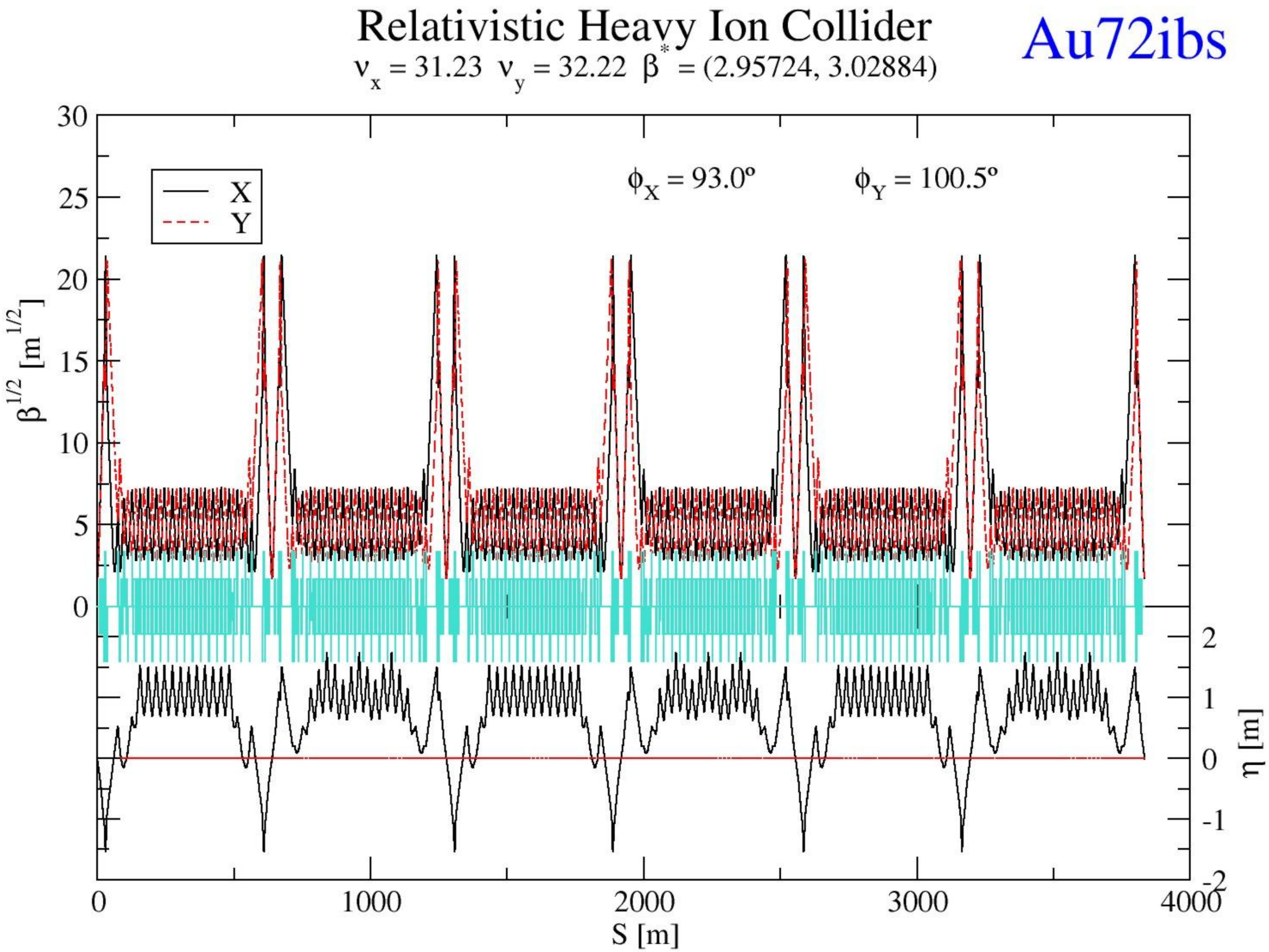
Final test

Blue with standard lattice

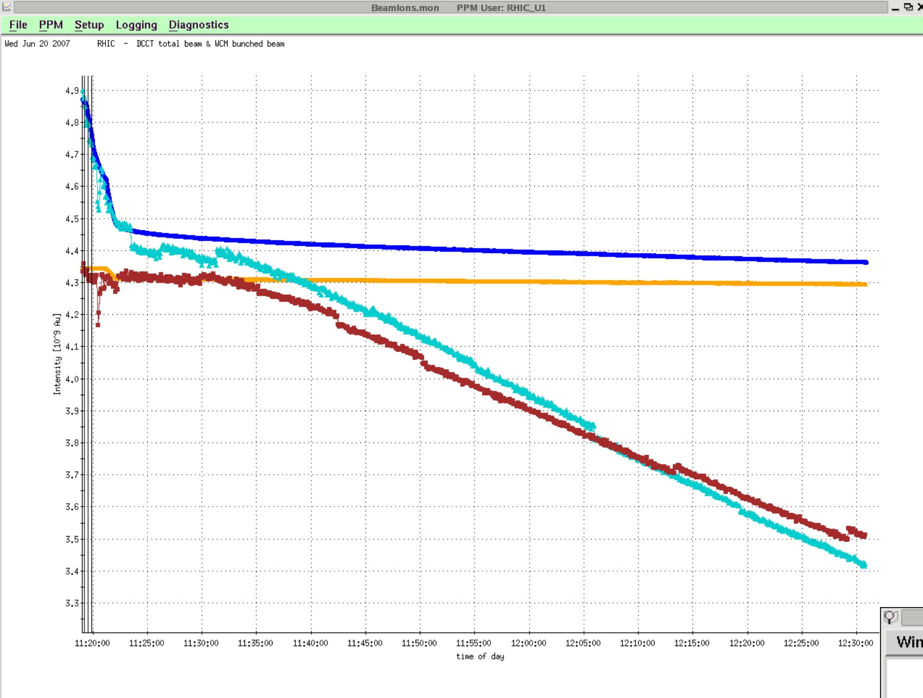
Yellow with IBS suppression lattice

Mei Bai, Don Bruno, Peter Cameron, Roger Connolly, John Cupolo, Al Della Penna, Alexei Fedotov, George Ganetis, Vladimir Litvinenko, Yun Luo, Nikolay Malitsky, Aljosa Marusic, Christoph Montag, **Vadim Ptitsyn, Todd Satogata, Steve Tepikian**, Nick Tsoupas

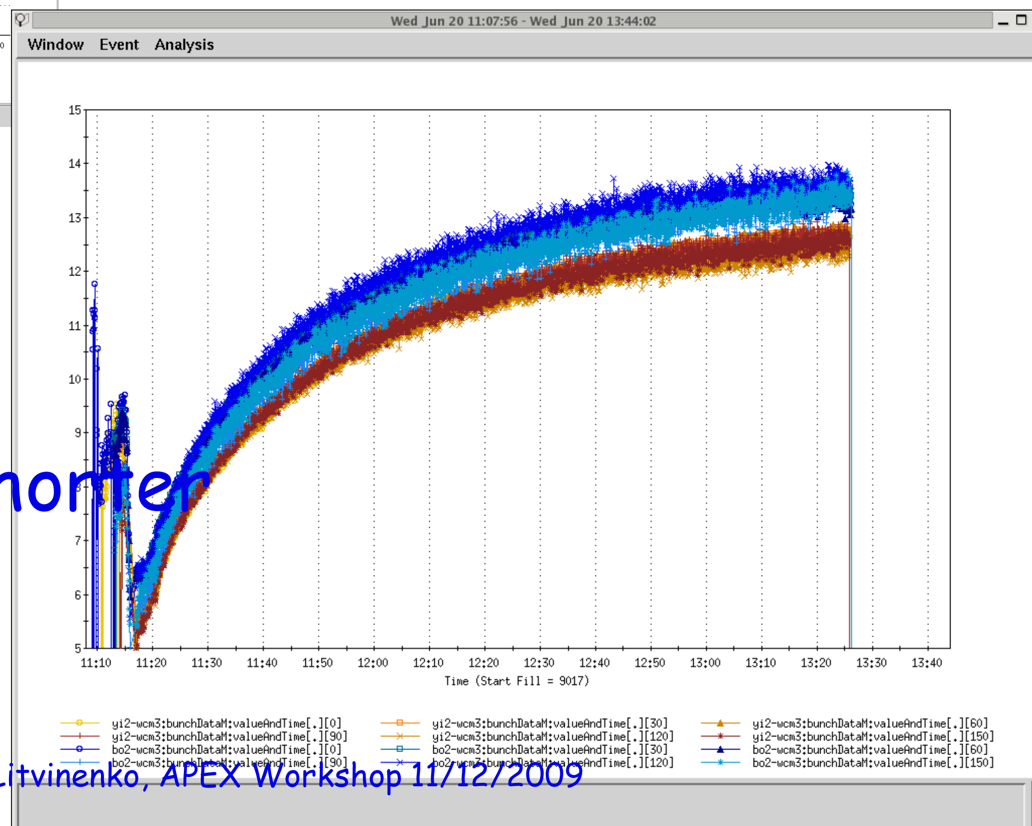
Au72ibs - Run 7



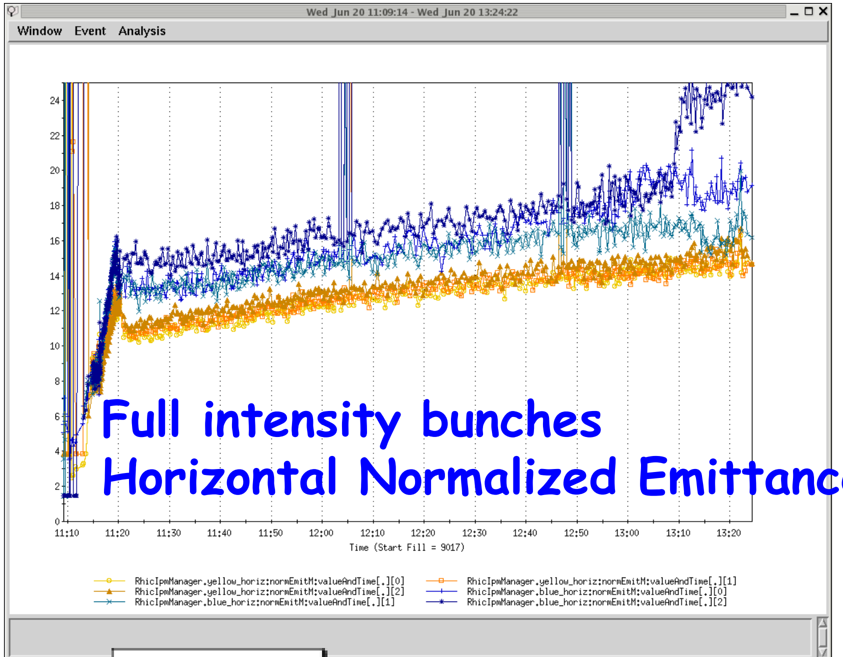
S. Tepikian



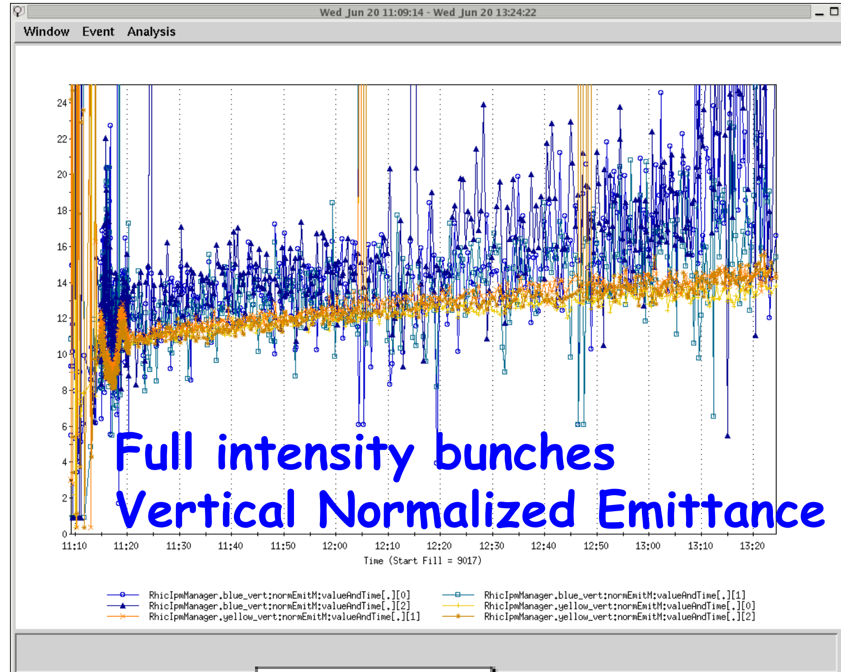
De-bunching:
Yellow is slightly better



Bunch lengths :
Yellow bunches are shorter
And stay shorter

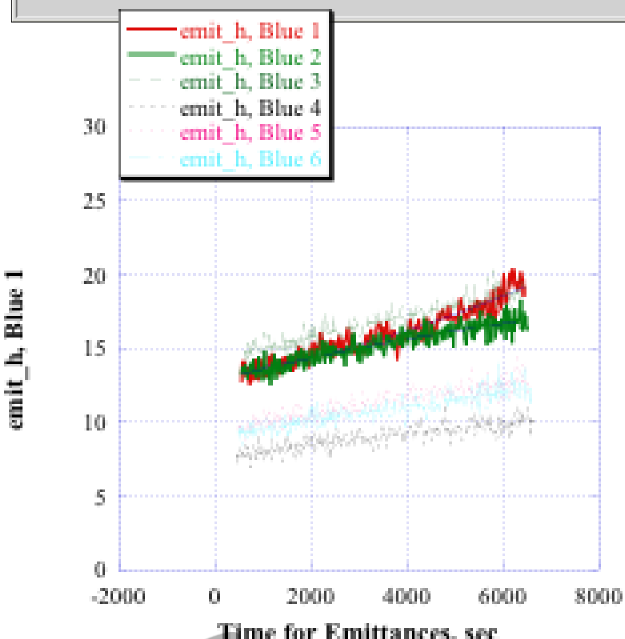


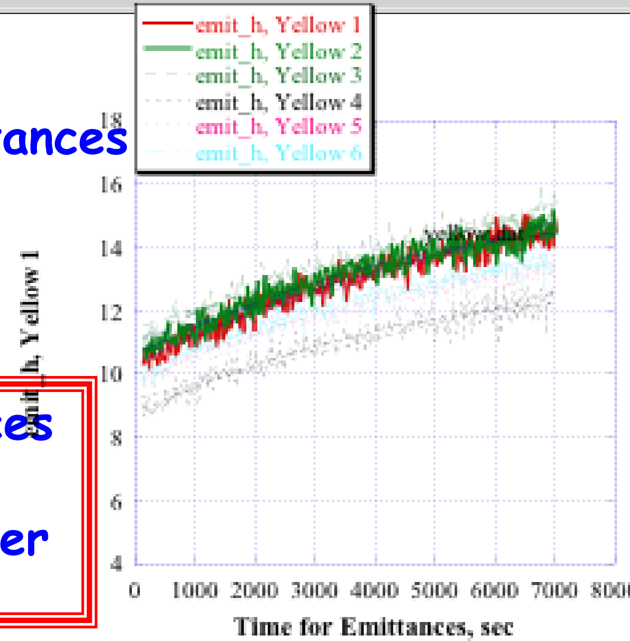
Full intensity bunches
Horizontal Normalized Emittance



Full intensity bunches
Vertical Normalized Emittance

Horizontal
Normalized Emittances



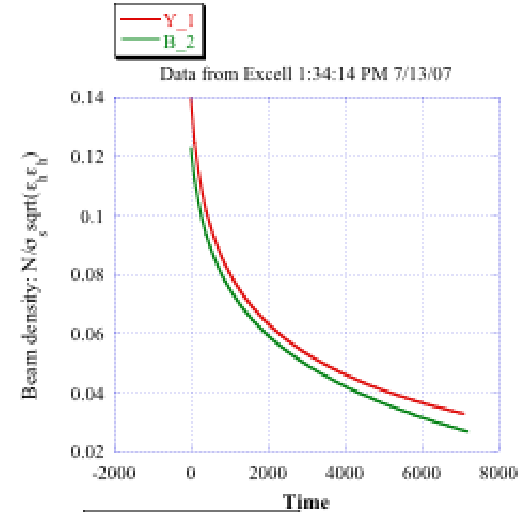


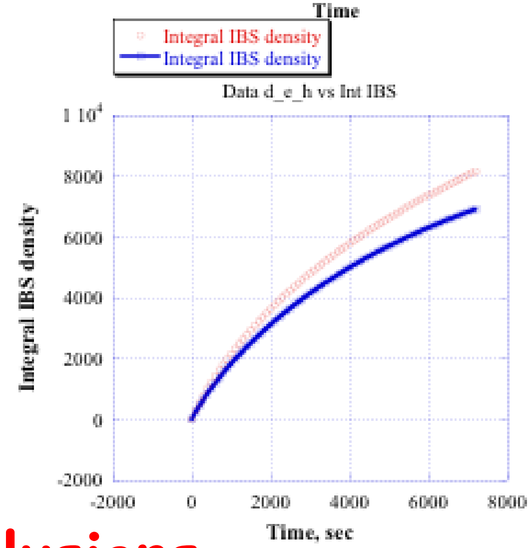
Yellow emittances
are smaller
and stays smaller

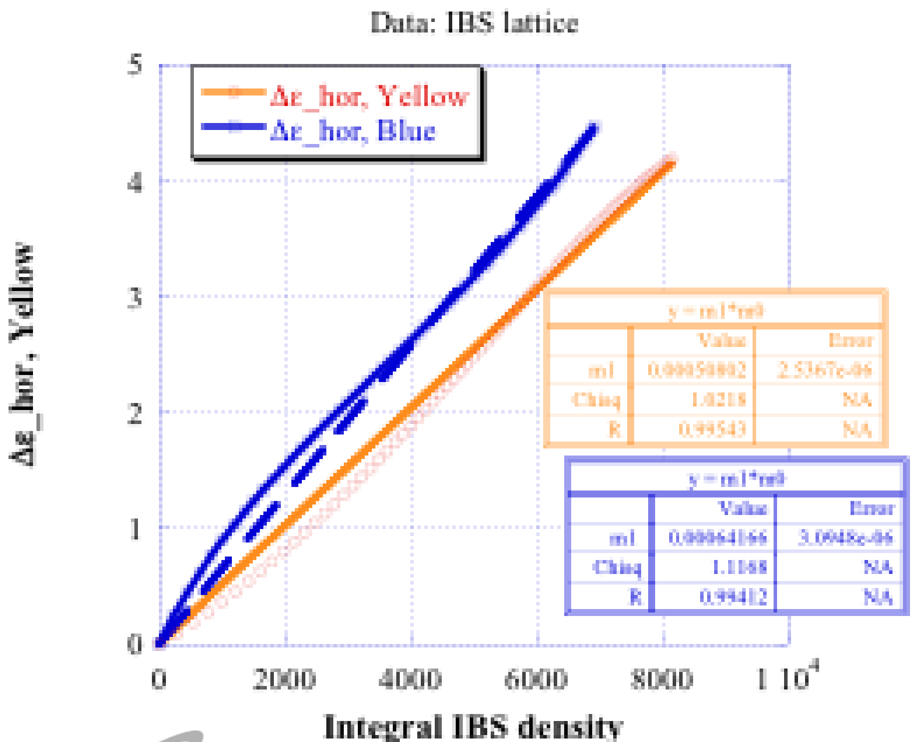
BROOKHAVEN
NATIONAL LABORATORY

IBS suppression lattice experiment

$$IBS \quad Integral \quad (t) = \int_{o}^{t} \frac{N(t')dt'}{\sigma_z \sqrt{\varepsilon_h \varepsilon_v (\varepsilon_h + \varepsilon_v)}}$$

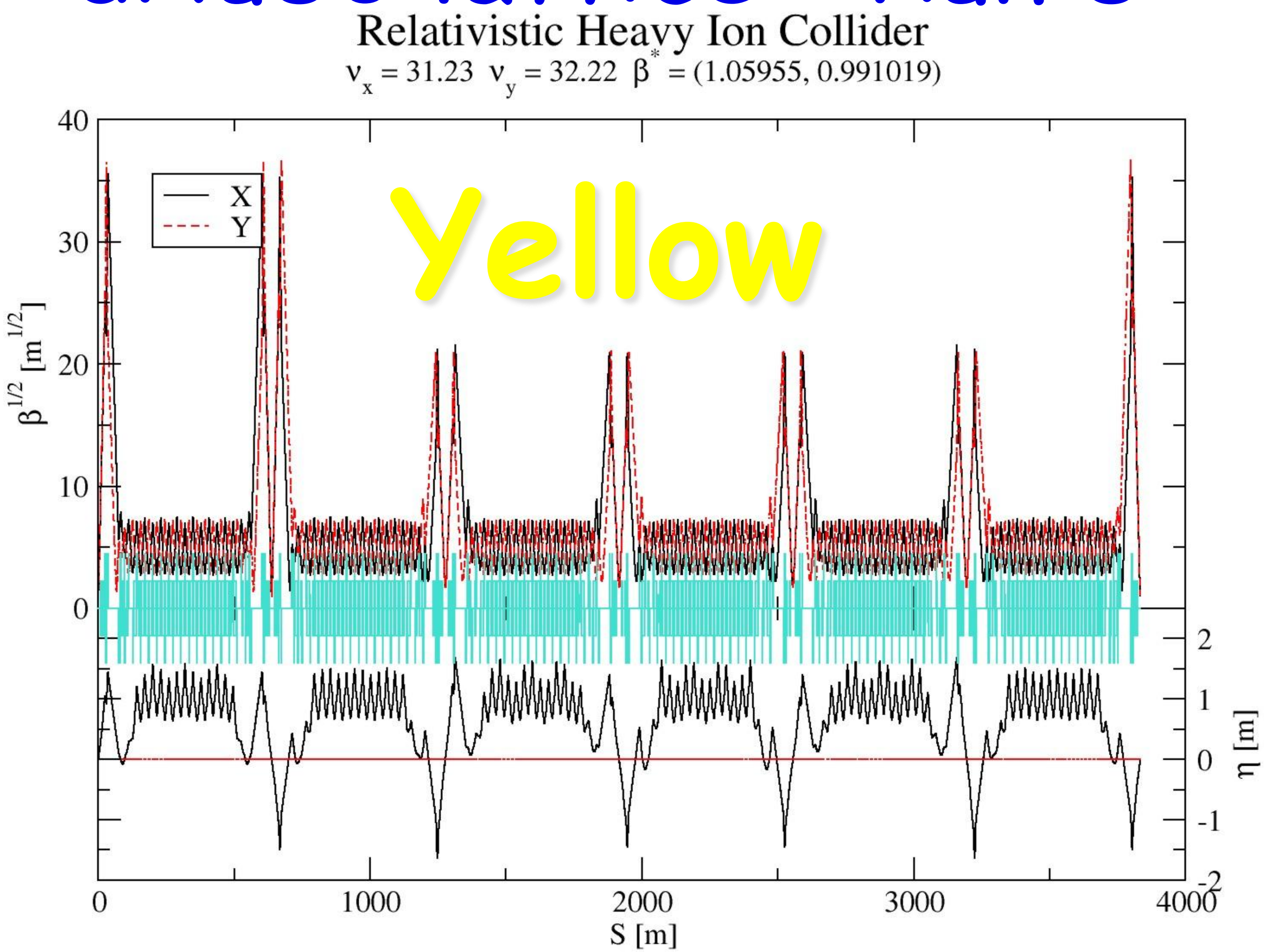






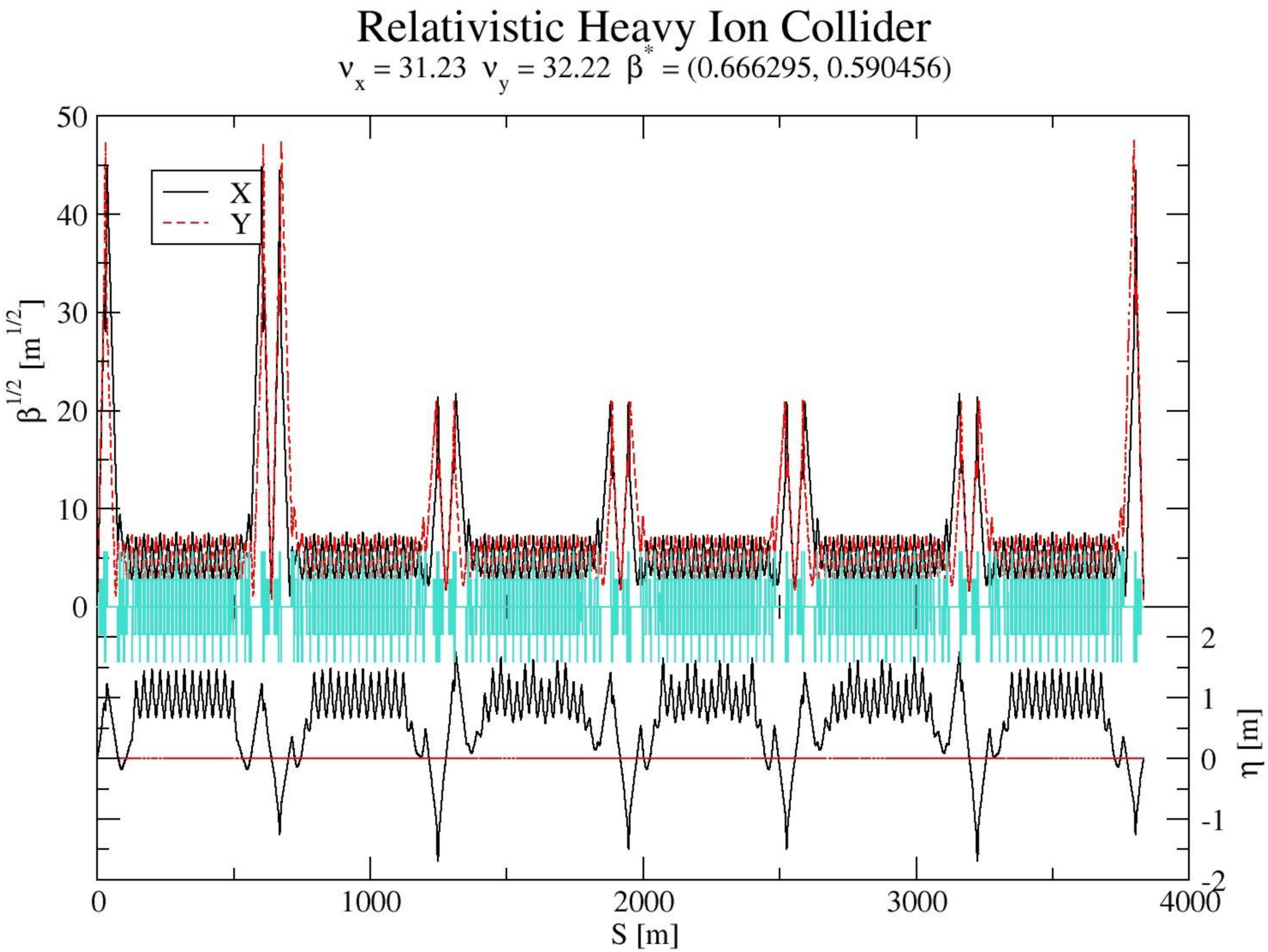
- **Conclusions**
  - **Transverse IBS is suppressed by 30±10%**

dAu80 lattice - Run 8



S. Tepikian

Au lattice for Run 8: β*-> 0.6 m



S. Tepikian

BROOKHAVEN NATIONAL LABORATORY

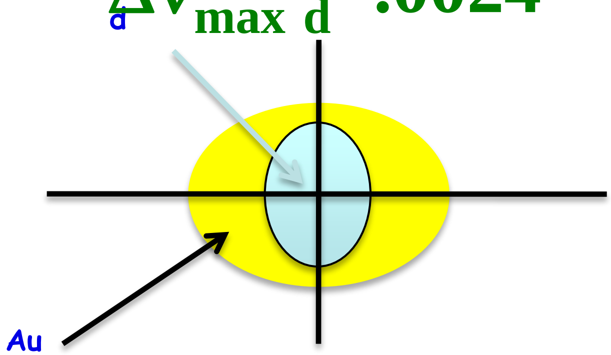
IBS lattice helped a lot in d-AU Run 08

Emittance of deuteron beam was very small

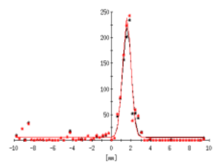
- Beginning of the store: Deuteron beam is 2 times smaller that Au beam
- End of the store (5.5 hrs recorded luminosity): Deuteron beam is 3 times smaller that Au beam

Run 8 dAu

$\Delta\nu_{max\ d}$=.0024



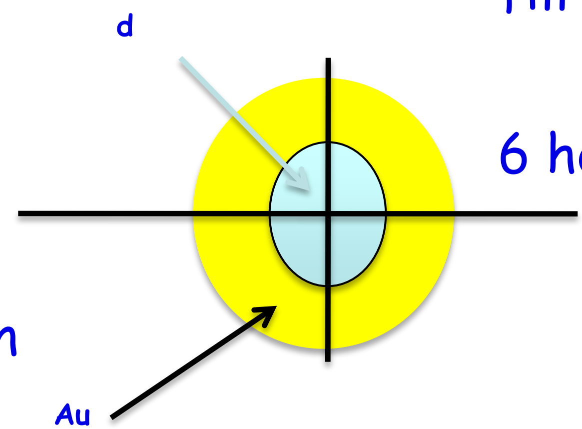
$\Delta\nu_{x\ Au}$=.0113



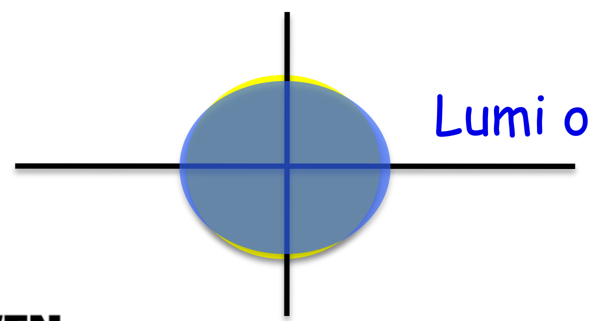
Lumi on

fill 9652

6 hours later



Run 7 AuAu

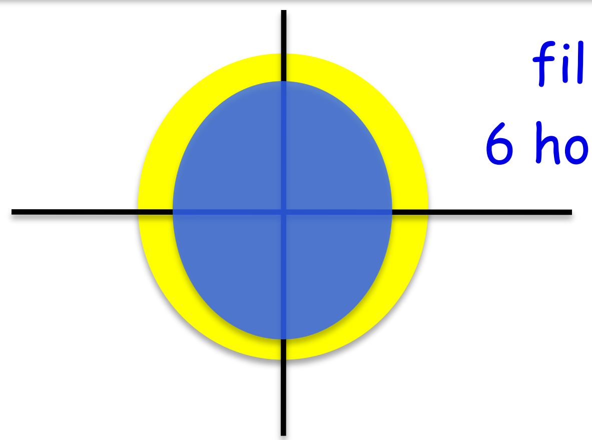


Lumi on

$\Delta\nu_{max\ Au}$=.0049

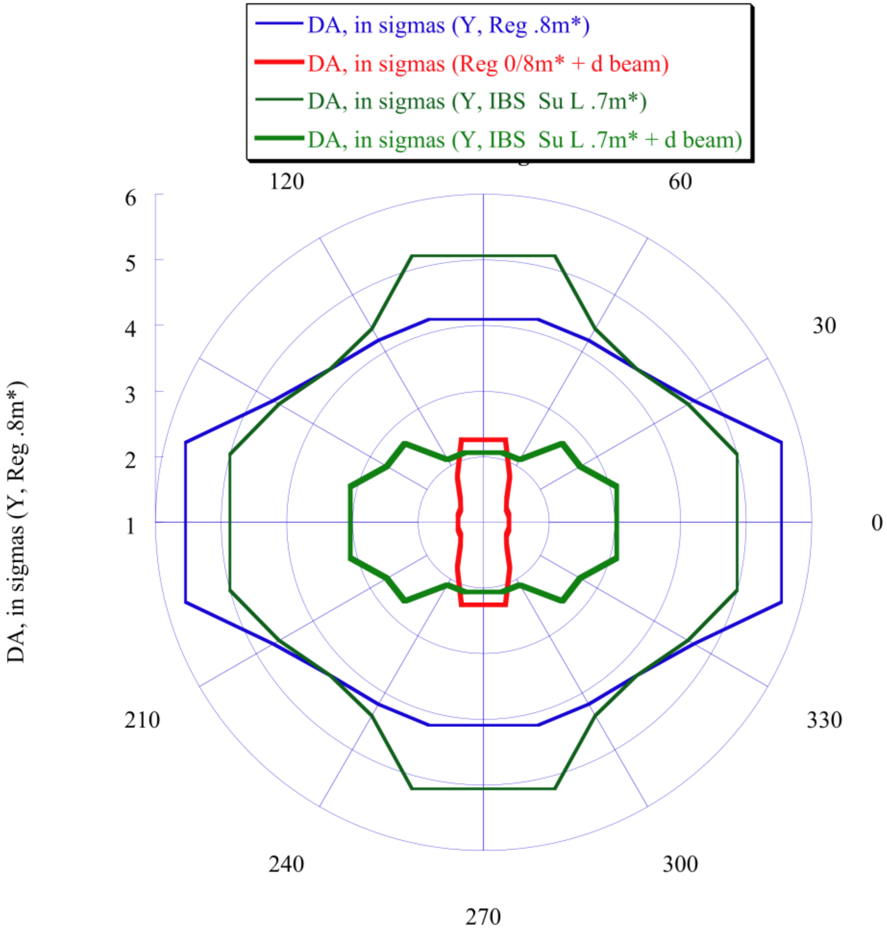
fill 8850

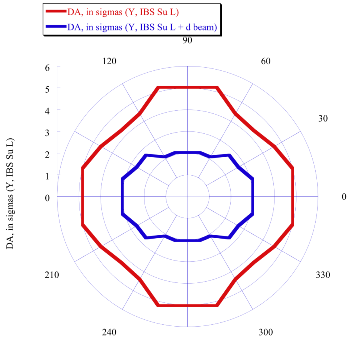
6 hours later



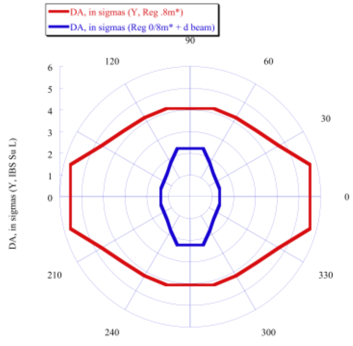
Dynamic Aperture with d-Au collisions IBS Su L vs. Regular (©Y.Luo)

- Dynamic aperture in regular lattice (even with β*=0.8m) is significantly worth
- **Most likely the squeeze to β*=0.8m would not be possible with regular lattice and all the luminosity from β* squeeze would be lost**





dp/p =1e-3; Au norm emittance 20 π mm mrad



Data DA Regular

BROOKHAVEN NATIONAL LABORATORY

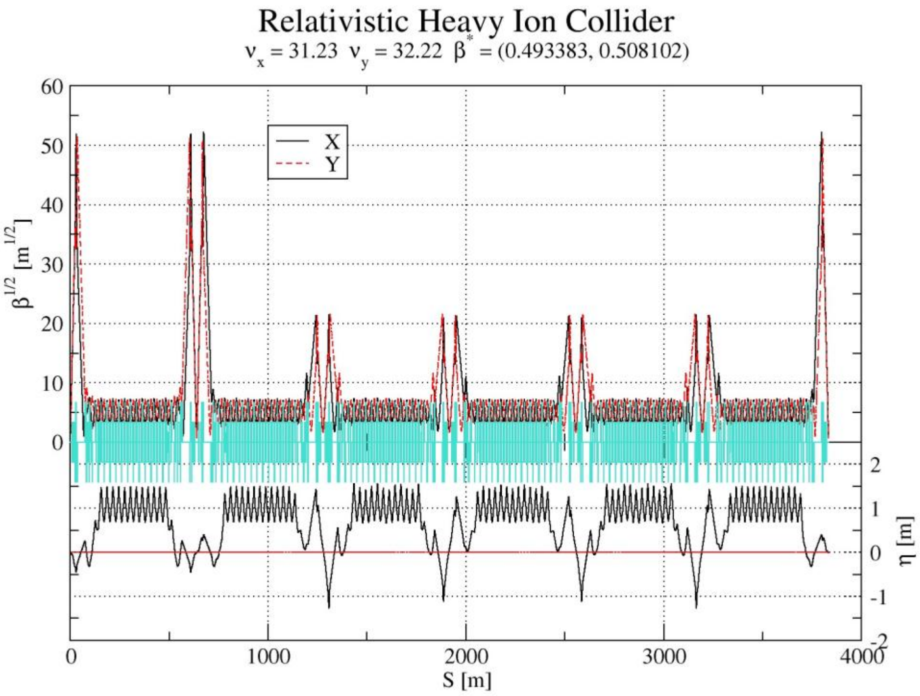
©Y.Luo

Main advantages of present day IBS suppression lattice

- Tune shift ~ 90 degrees per cell provides for a larger dynamic aperture
- IBS suppression lattice is natural match for lower β^* and is a good candidate for $\beta^*=0.5$m
- Without cooling, β^* for IBS lattice can be reduced b by 20-25% from that in the standard lattice resulting 20-25% increase in luminosity
- Worked very well with stochastic cooling, higher γ_t and low slip factor may allow to increase band-width of the system
- 13% RF bucket acceptance increase because of higher γ_t by 13%, i.e. center bunch intensity will be 13% larger for IBS lattice. It becomes even more important when beam are cooled transversely.
- It provided for 13% increase in the vertex luminosity for D-Au and the case of Au-Au it should be at least 28%

Prospects

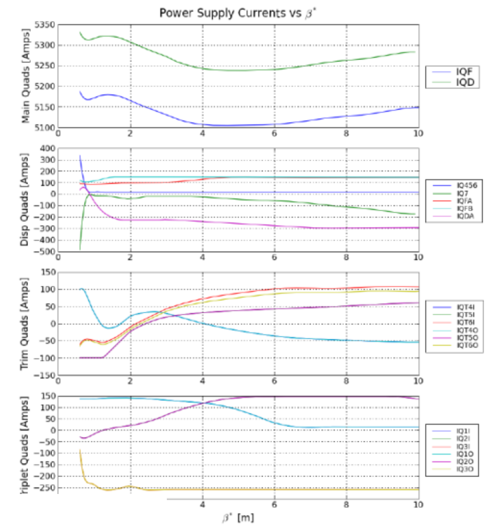
- 2-fold suppression of transverse IBS
- Smaller slippage and Shorter bunches
- Even Smaller β^*
- More surprizes
- More good stuff….



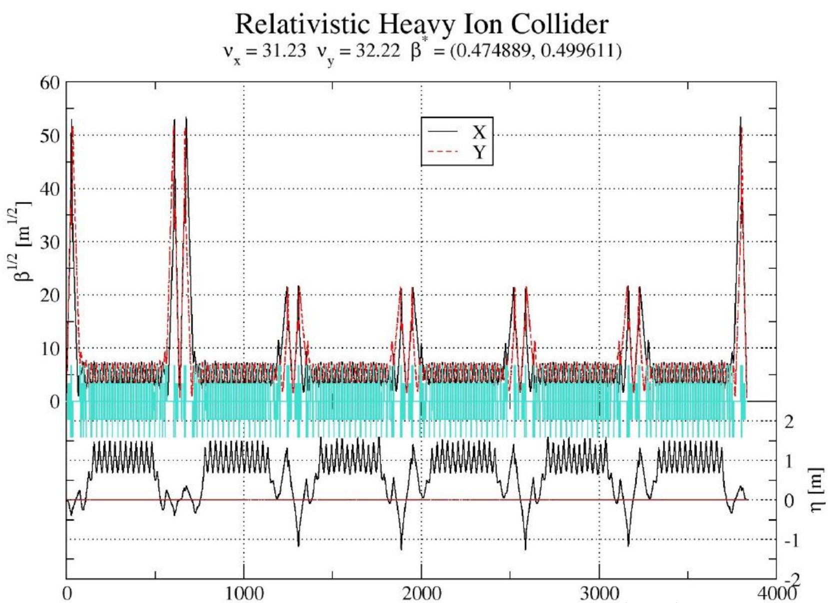
IBS suppression optics β*=0.5m
S. Tepikian

- Raise the tune by +3 units in both planes
  - Tune is adjusted with arc FODO cells
  - Different arc FODO cell to match to the IR
  - Different dispersion for the dispersion suppressor
- Try different initial guess for the IR quadrupole
- Power supply currents are quite different
- β* = 0.5*m* is achievable without upgrades to power supplies or additional quadrupoles

- Run-8: Gold at 100GeV/nucleon
- PSQ7 is reversed
- Trims hit limits
  - PSQT4I and PSQT4O
  - PSQT5I and PSQT5O
- Limits at large β*
  - PSQDA
  - Poor dispersion



Set expected limits for the trim quadrupole power supplies (150Amps) and Q89 bipolar power supplies (±290Amps)



BROOKHAVEN
NATIONAL LABORATORY

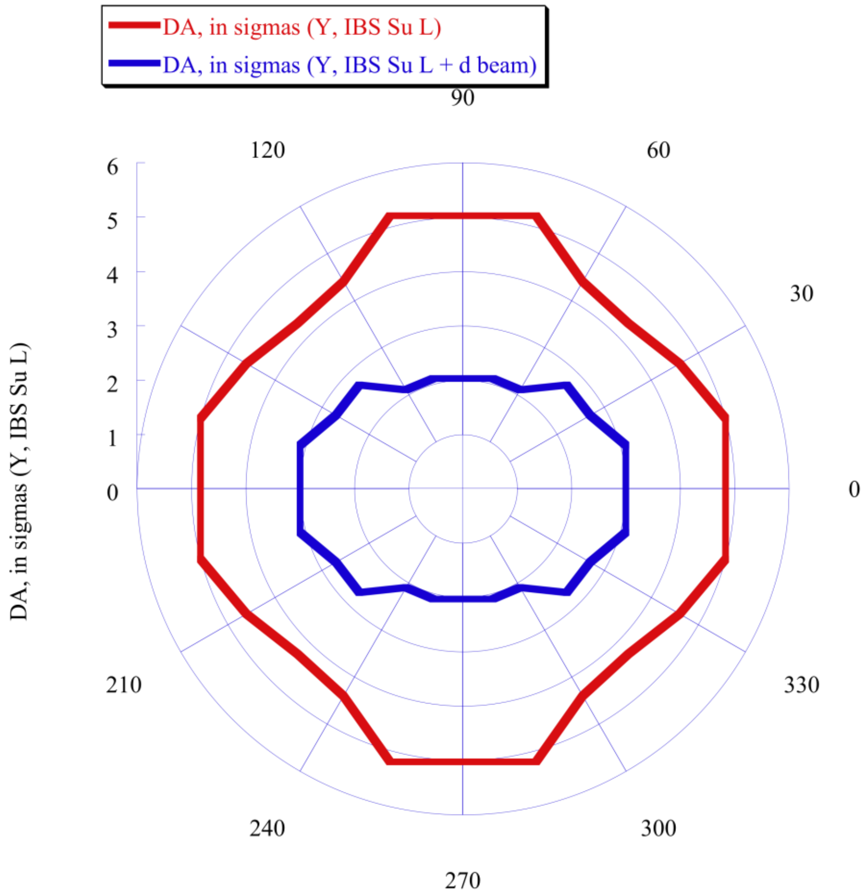
Never Forget Hardware Limitations

- Power supplies, leads and quenching
- Current distribution limitations - H & V strings, the tree of shunting PS - Polarity of trim power supplies
- Sextupole strength!
- Growth of γ_t and strength of γ_t quads
- Matching with desirable β^*
- Dynamic aperture
- Effects on coupling compensations scheme, diagnostics using specific tune advances, etc....

Conclusion

- Developing an operational IBS suppression lattice was one of APEX success stories
- There were large number of pleasant surprises
  - It is good for stochastic cooling
  - Many luminosity gains were indirect and come from other effects than simple reduction of the IBS growth (better DA, naturally smaller β^*, shorter vertex, larger energy acceptance, possibility to split γ_t crossings, etc.)
- Present IBS suppression lattice is selected for Run 10 *and we will need to evaluate how it would contribute into the luminosity gains*
- Exploring further suppression of IBS and creating new lattices with tune advance per cell ~110^o to reach about factor two suppression in transverse IBS
- Consider how 90^o IBS suppression lattice can be used for polarized proton runs (running at 2/3 resonance, improving DA…)

Dynamic Aperture



dp/p =1e-3; Au norm emittance 20 π mm mrad

- Dynamic aperture of IBS suppression lattice is about 5σ for emittance of 20 mm mrad (norm, 95%), i.e. acceptance of 500 mm mrad
- **Collisions with 10^{11} deuterons having 7 mm mrad emittance (norm 95%) reduces the dynamic aperture for Au beam to 2.1-3σ, i.e. reduces the acceptance to 90-180 mm mrad**
- This dramatic reduction of the DA caused the reduction of the AU beam lifetime (losses) and required aggressive collimation during the most of the dAu Run8

©Y.Luo

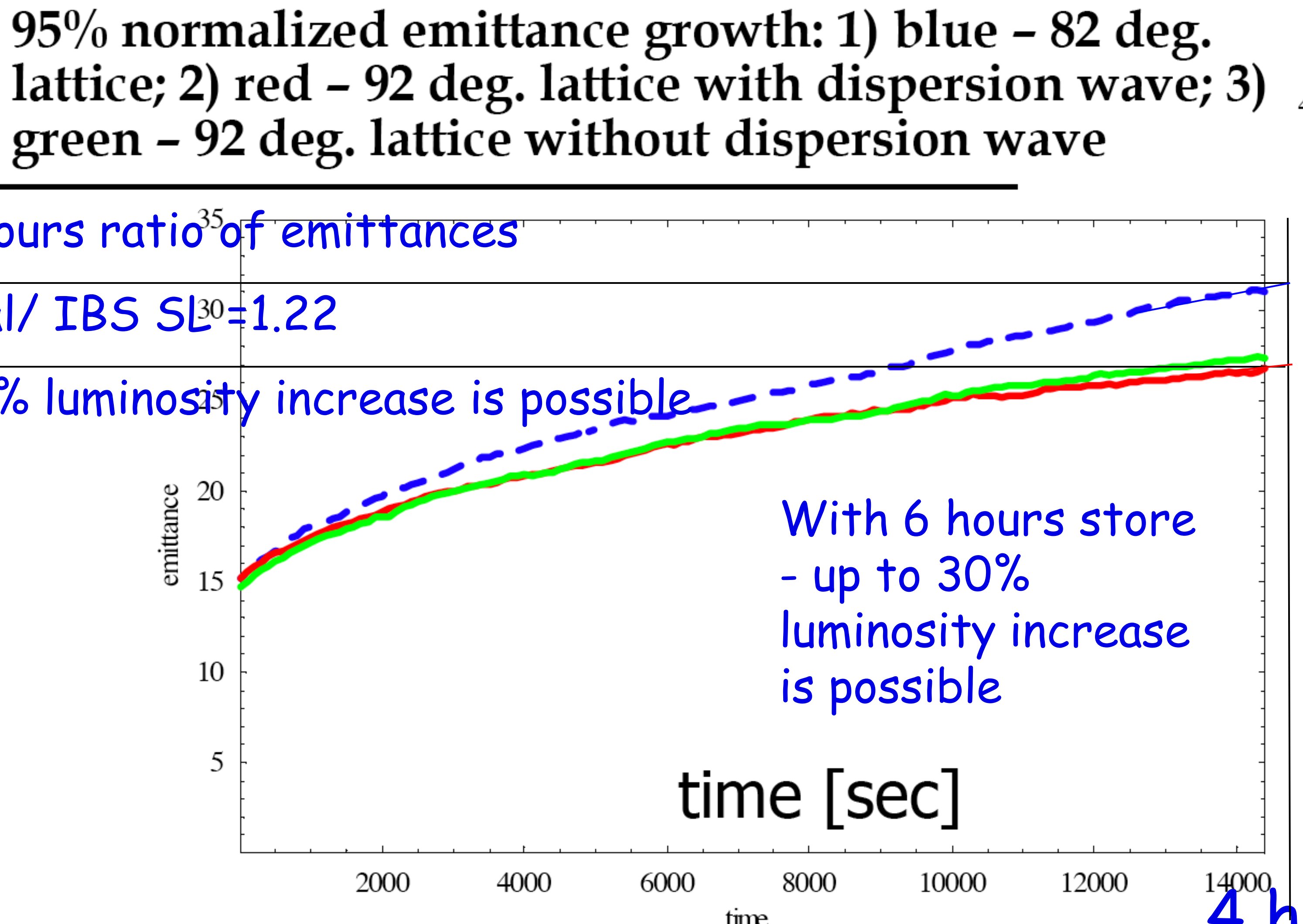
BROOKHAVEN
NATIONAL LABORATORY

Main advantage comes from beta*

In 4 hours ratio of emittances

Normal/ IBS SL=1.22

i.e. 22% luminosity increase is possible



With 6 hours store - up to 30% luminosity increase is possible

4 hours